

Cambridge Judge Business School

Cambridge Centre for Risk Studies

# The economic impact of extreme space weather: *Exploratory evidence*

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2<sup>nd</sup> May 2017

US Space Weather Workshop

Centre for  
**Risk Studies**



UNIVERSITY OF  
CAMBRIDGE  
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# Presentation Overview

Background  
and motivation

Methodology

Results and  
conclusions

# Standard Disclaimer

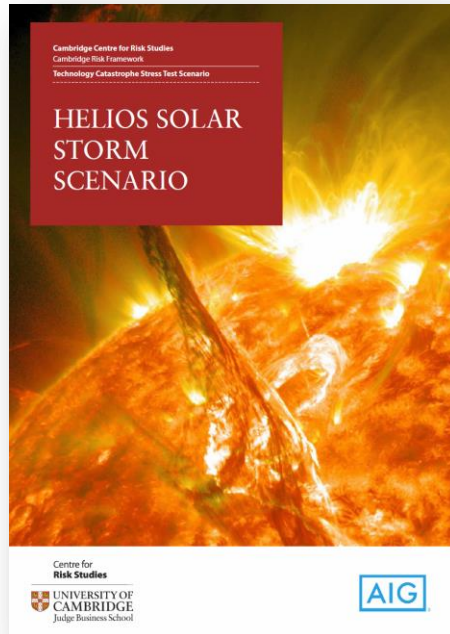
- The scenarios presented are not predictions
- They do not try to highlight any specific vulnerability in any power grid system
- Think of the work as exploring the sensitivity of the economy to the storm impact area
- This is a useful stress testing tool for risk management purposes

# Context from the Regulator: PRA General Insurance Stress Test 2015



# Background

## Helios global insurance stress test



## Academic paper



The academic paper is *very different* from the Helios Scenario

- Helios reflects the most *extreme* expert opinions on space weather
- It produces large numbers – the most extreme scenario is a trillion dollar event
- The working paper is a more rigorous, scientific contribution
- It focuses on *daily* economic loss, avoiding the debate over temporality

# Workshop: The Economics of Space Weather



*Cambridge, 29<sup>th</sup> July 2015*

This event gathered representatives from:

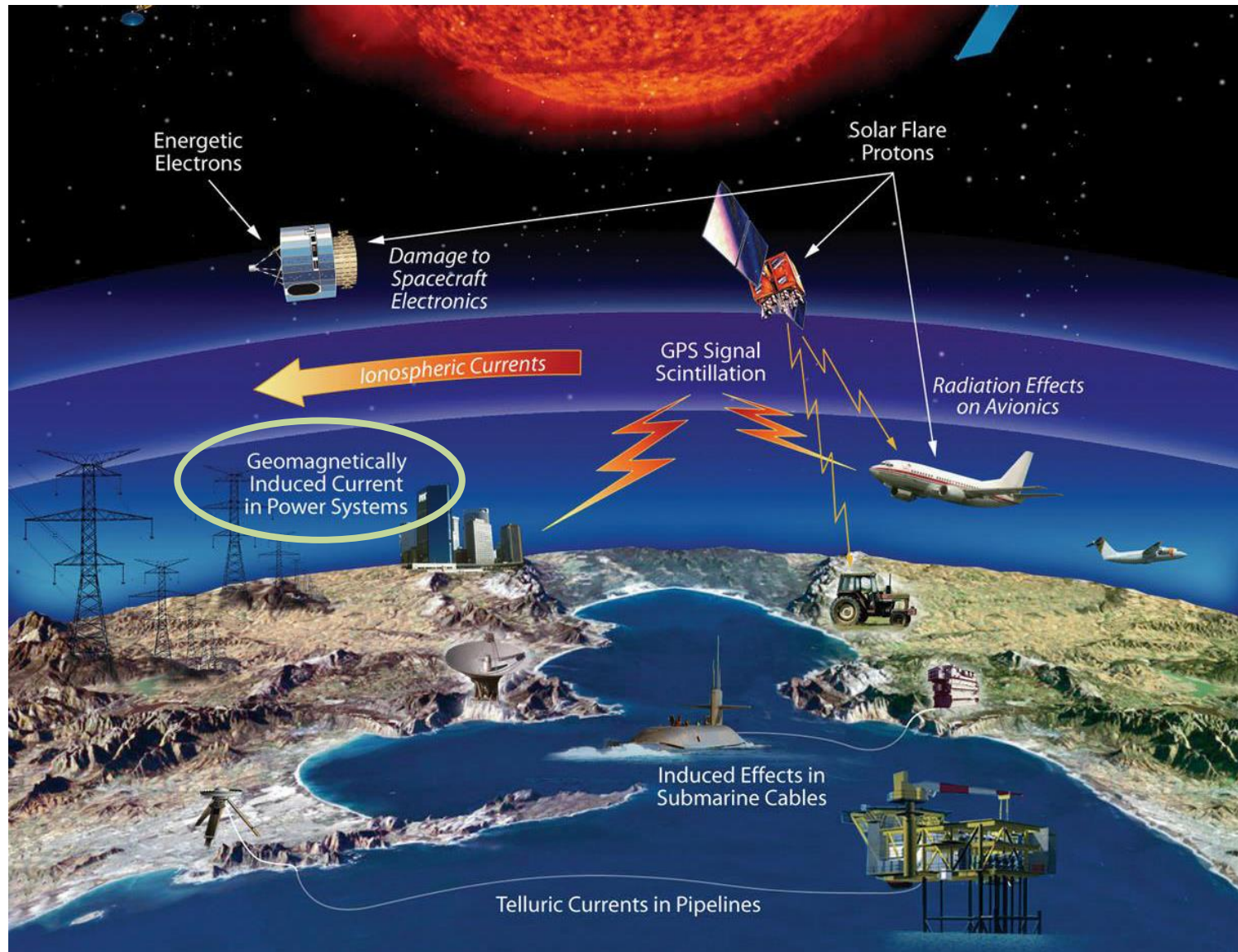
- Space physics
- Economics
- Catastrophe modelling
- Actuarial science
- Engineering
- Law
- Property, casualty and space insurance

Subject Matter Experts consulted in this process:

- Richard Horne (BAS)
- Helen Mason (Cantab)
- Alan Thomson (BGS)
- Trevor Gaunt (UCT)
- David Boteler (NRCan)
- Mark Clilverd (BAS)



# Focus: GIC Risk to Electricity Transmission Infrastructure



# EHV Transformers: Many Supply Chain Issues



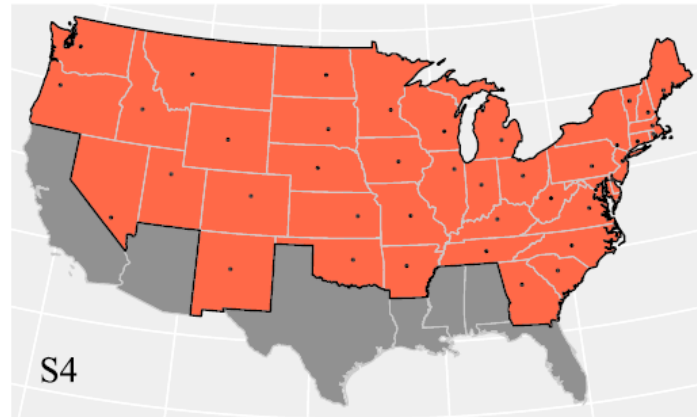
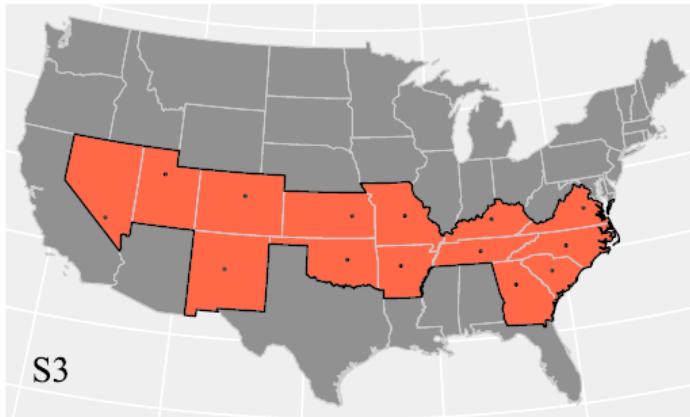
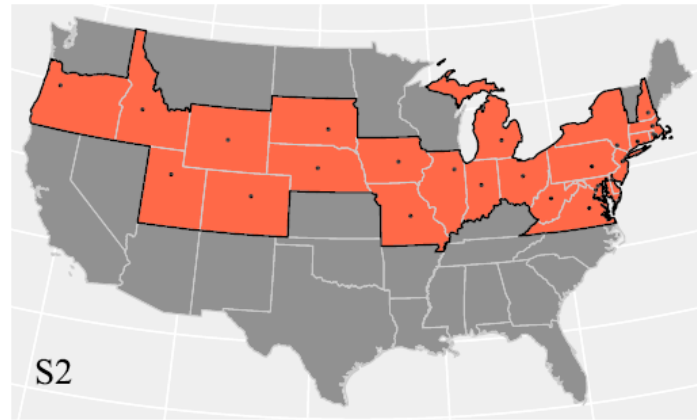
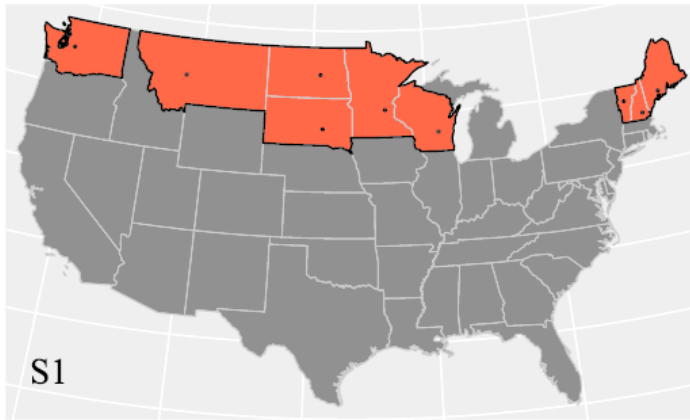
# Methodology

The methodology presented here flows sequentially through the following main steps:

1. Determining blackout zone by scenario;
2. Calculating the direct economic impact by state;
3. Aggregating the direct economic impacts by state to national industry-specific impacts;
4. Estimating indirect domestic and global economic impact.

We focus on the USA for a number of reasons including absolute economic size, insurance penetration, regulatory emphasis etc.

## Step 1: Blackout Zone by Scenario



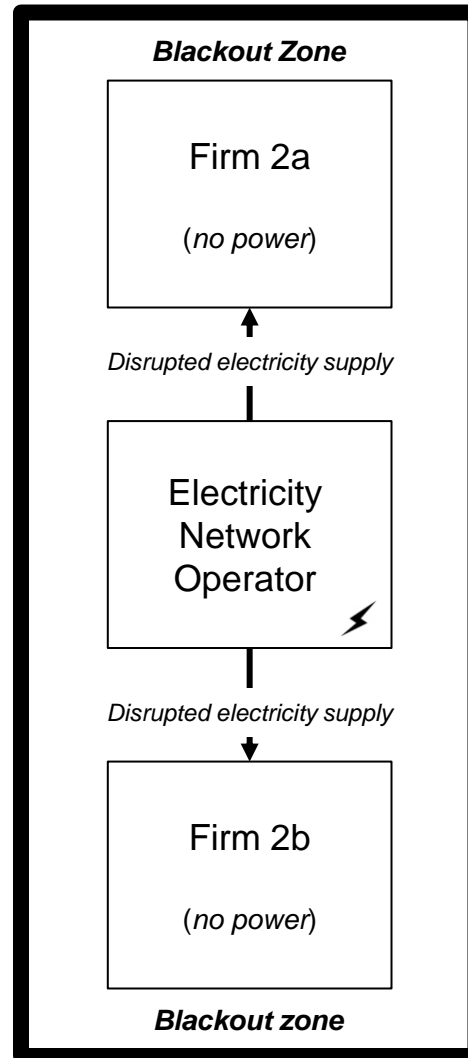
Blackout  
Zone

State Affected

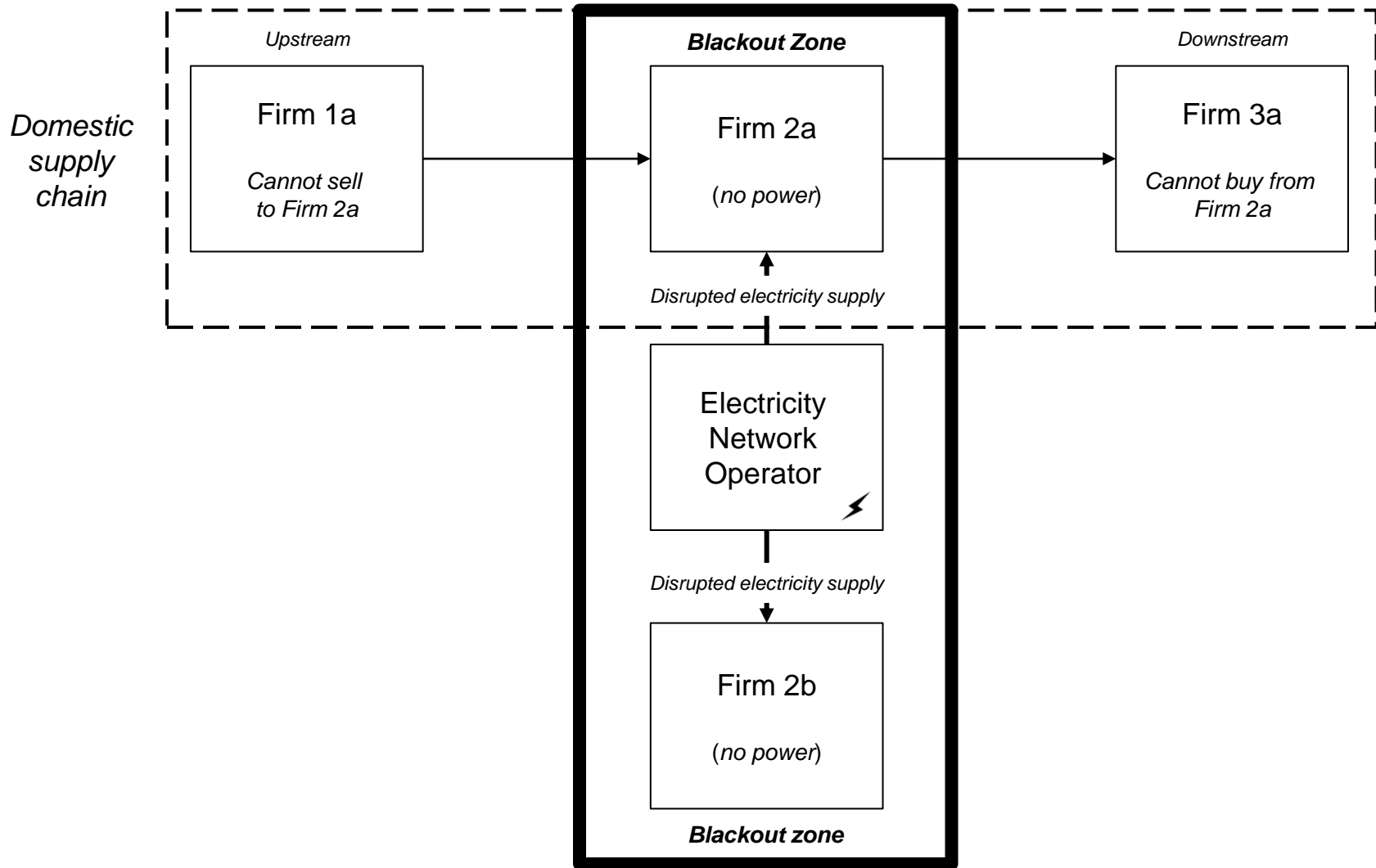
State Not Affected

*States included in each scenario based on the geomagnetic latitude of the (weighted) population centre*

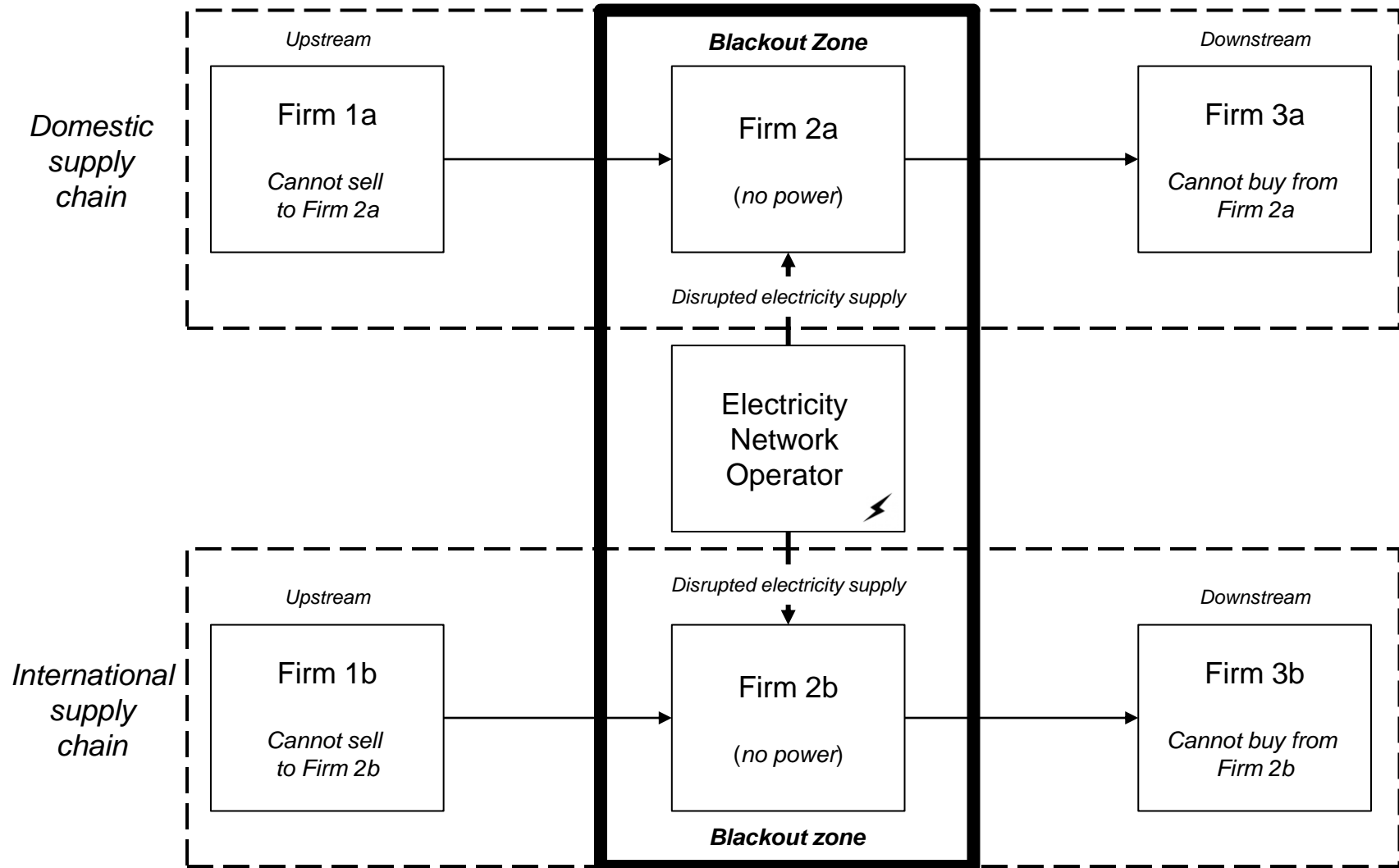
# Direct and Indirect Economic Impacts



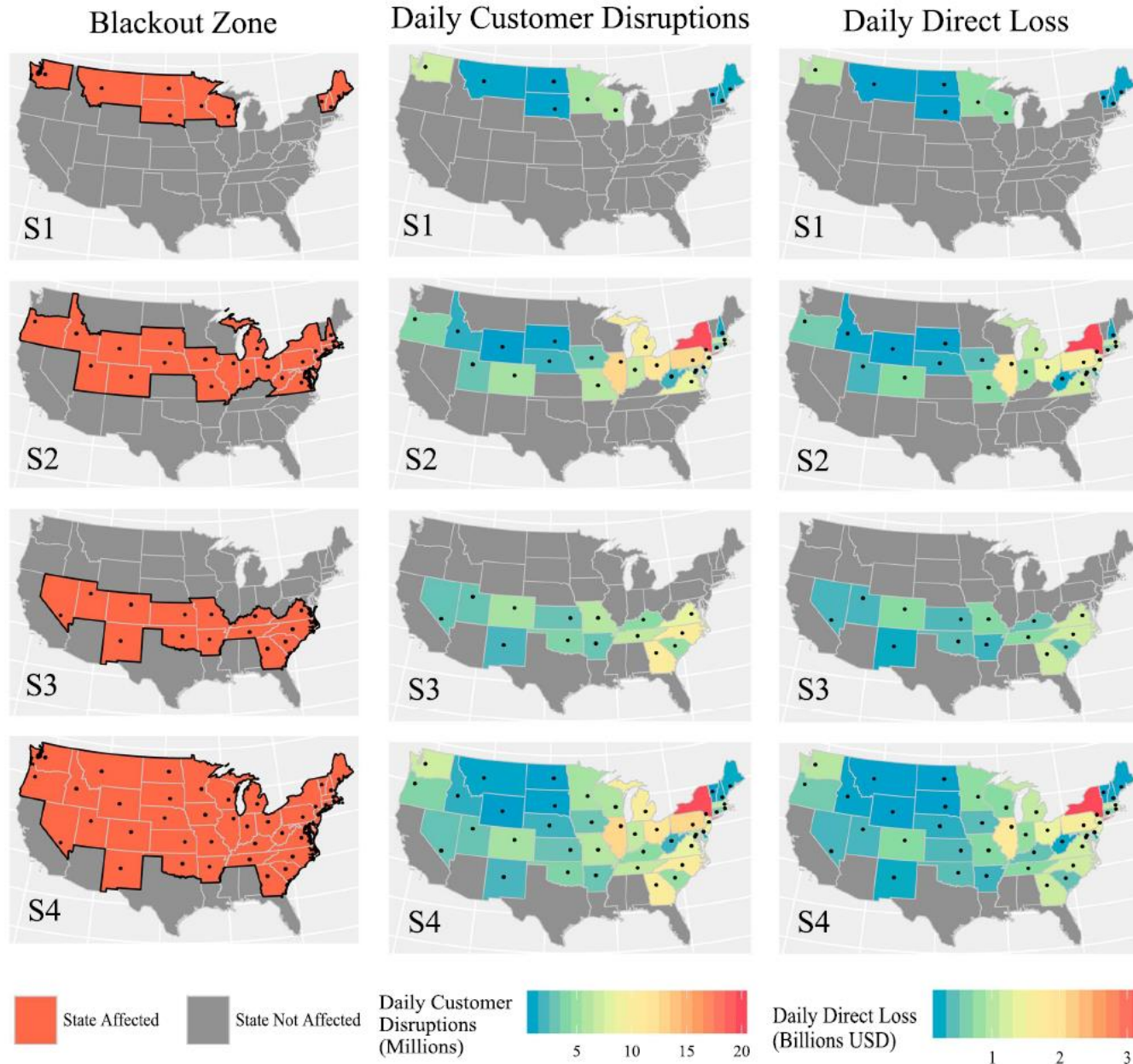
# Direct and Indirect Economic Impacts



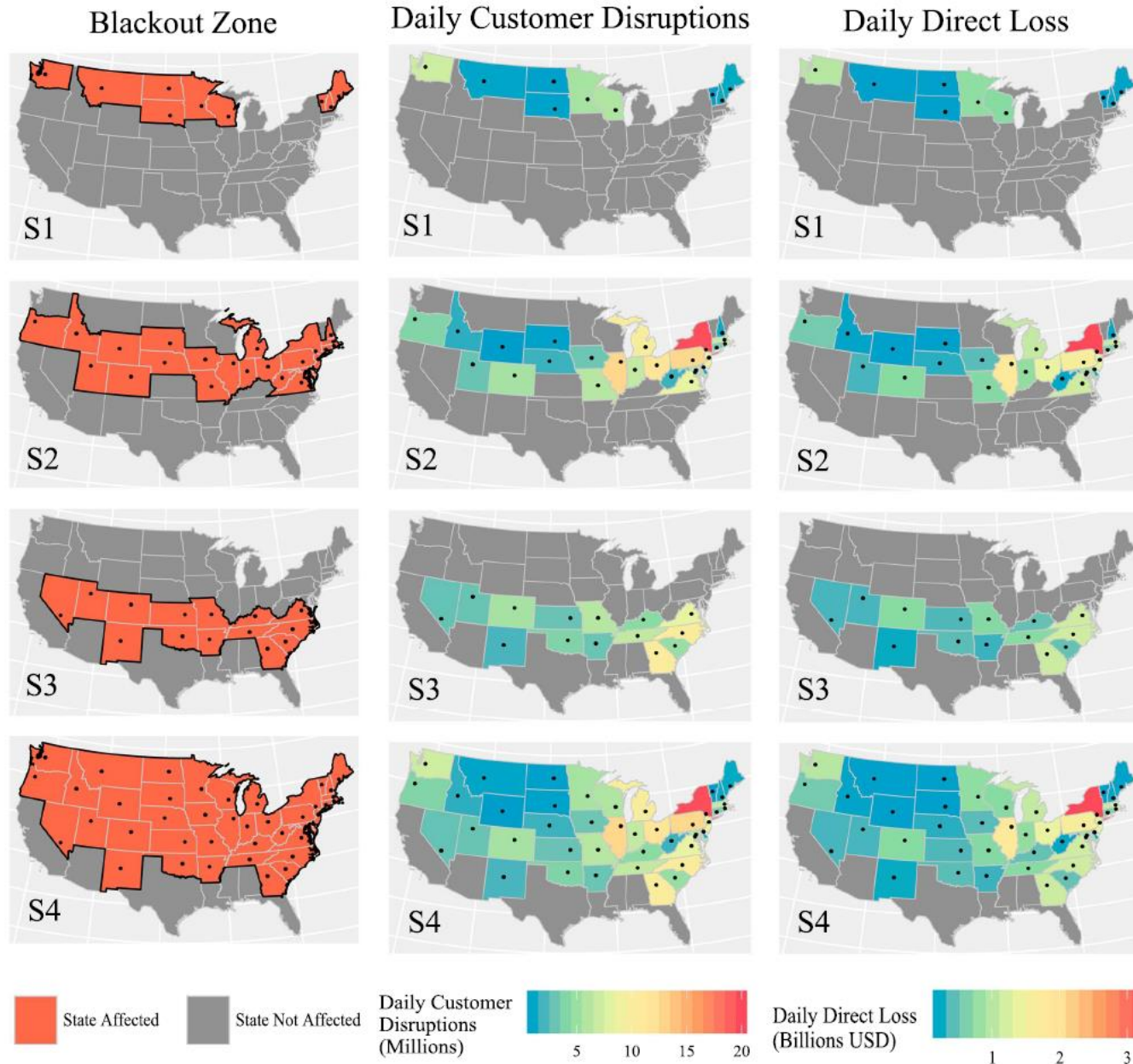
# Direct and Indirect Economic Impacts



# Step 2: Calculating the Direct Economic Impact



# Step 2: Calculating the Direct Economic Impact



**Step 3:**  
**Aggregation**

# Step 4: Estimating of indirect domestic and global economic impact

Classic Leontief IO model	$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1} \mathbf{y}$	1
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Supply-side Ghosh IO model	$\mathbf{x} = \mathbf{v}(\mathbf{I} - \mathbf{B})^{-1}$	2
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Upstream economic impact	$\Delta \mathbf{x}_s^{\text{up}} = (\mathbf{I} - \mathbf{A}^*)^{-1} \mathbf{A}_{:,s} \Delta x_s$	3
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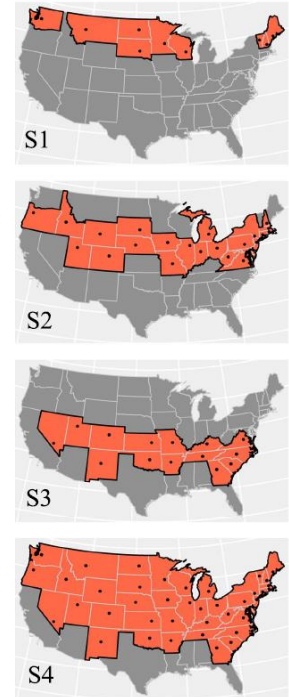
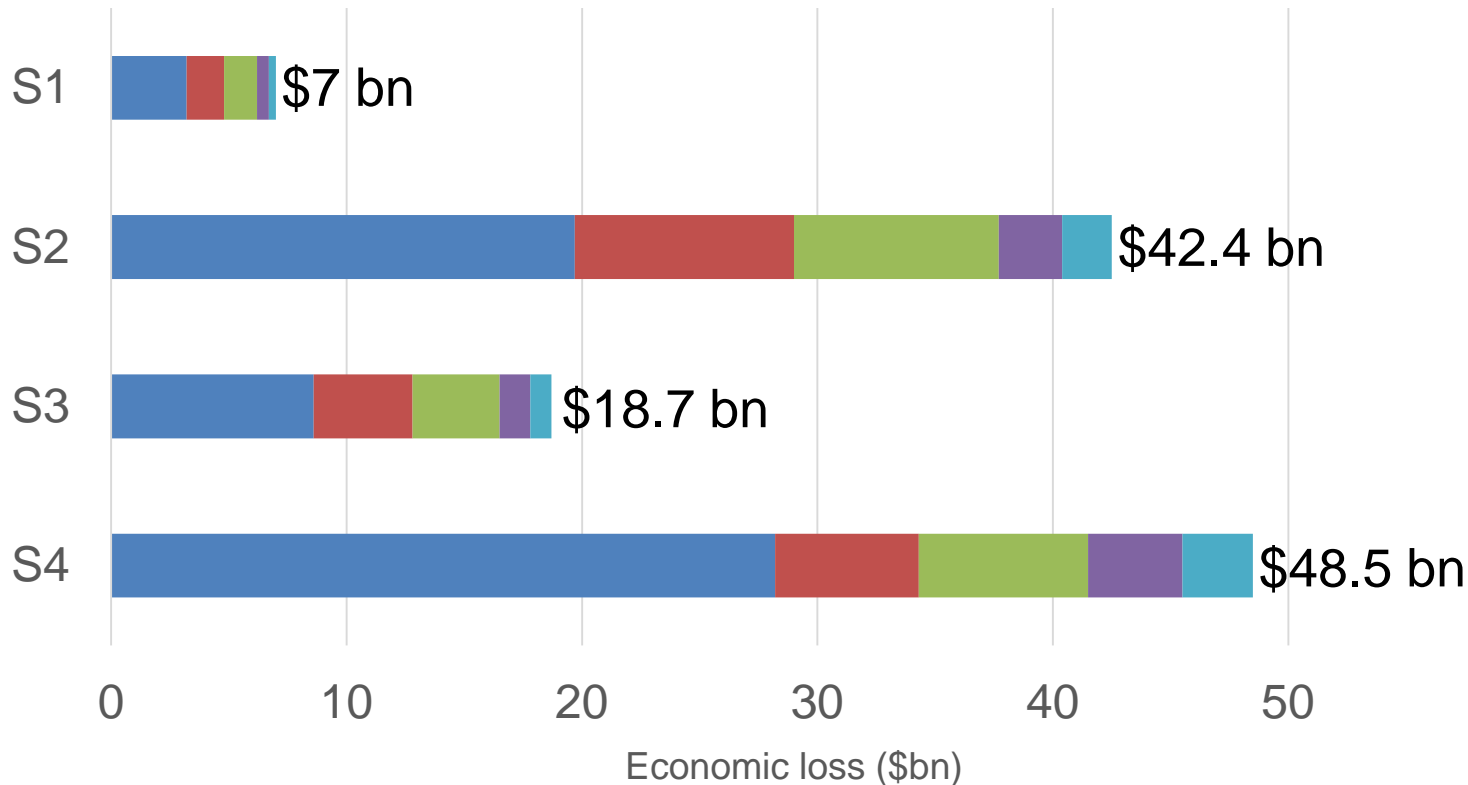
Downstream economic impact	$\Delta \mathbf{x}_s^{\text{down}} = \Delta x_s \mathbf{B}_{s,:} (\mathbf{I} - \mathbf{B}^*)^{-1}$	4
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Feedback impact	$\Delta \mathbf{x}_s^{\text{fb}} = \mathbf{A}_{s,:} (\mathbf{I} - \mathbf{A}^*)^{-1} \Delta \mathbf{x}_s^{\text{up}} = \Delta \mathbf{x}_s^{\text{down}} (\mathbf{I} - \mathbf{B}^*)^{-1} \mathbf{B}_{s,:}$	5
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Total output shock vector	$\Delta \mathbf{x}^{\text{total,lb}} = \min_s \left[ \Delta \mathbf{x}^{\text{dir}}, \min_s \Delta \mathbf{x}_s^{\text{up}}, \min_s \Delta \mathbf{x}_s^{\text{down}}, \min_s \Delta \mathbf{x}_s^{\text{fb}} \right]$ $\Delta \mathbf{x}^{\text{total,ub}} = \Delta \mathbf{x}^{\text{dir}} + \sum_s \Delta \mathbf{x}_s^{\text{up}} + \sum_s \Delta \mathbf{x}_s^{\text{down}} + \sum_s \Delta \mathbf{x}_s^{\text{fb}}$	6
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# Daily Economic Loss by Scenario

Total lost value by type



■ US direct loss (\$bn)

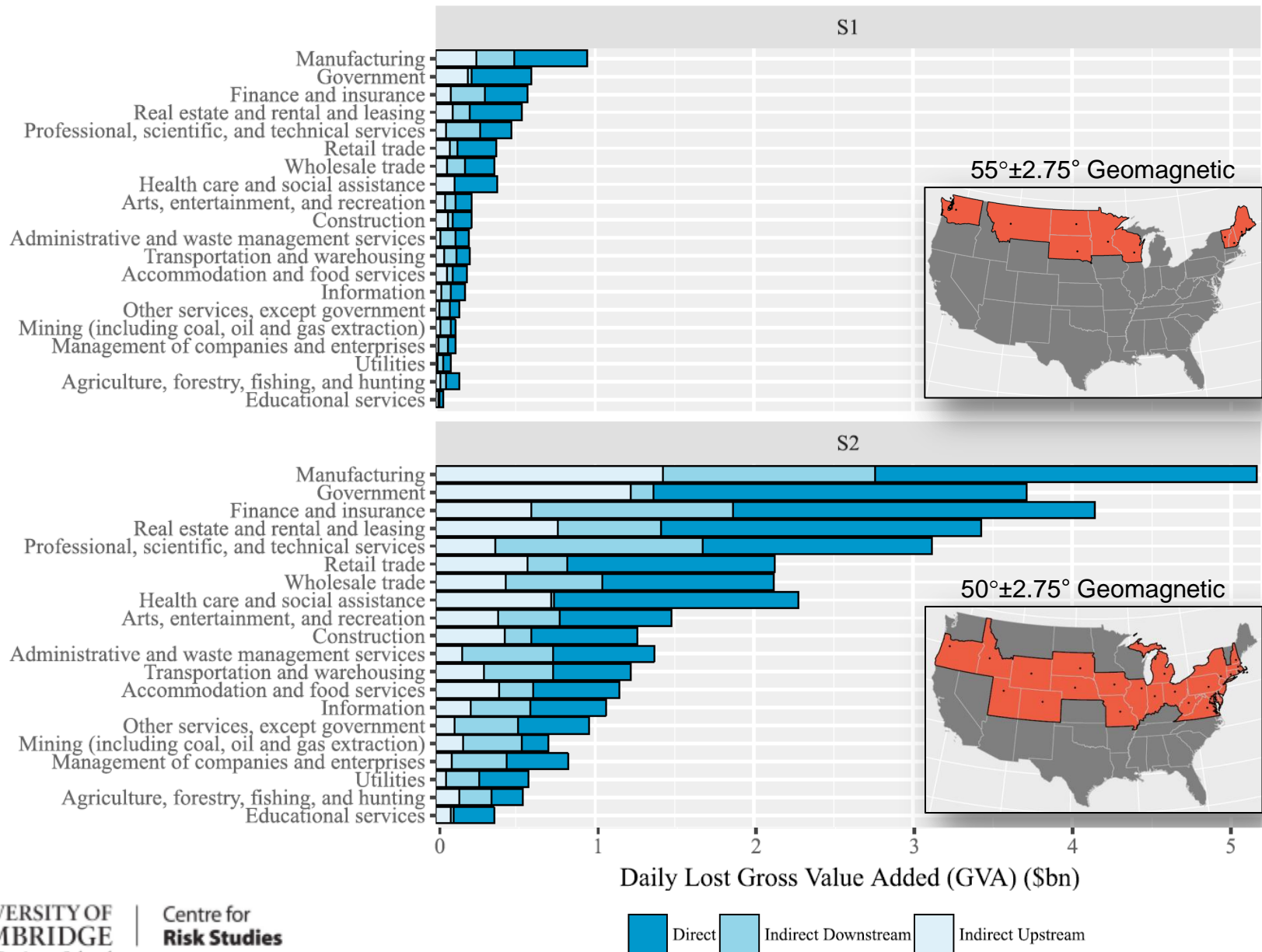
■ US indirect downstream loss (\$bn)

■ US indirect upstream loss (\$bn)

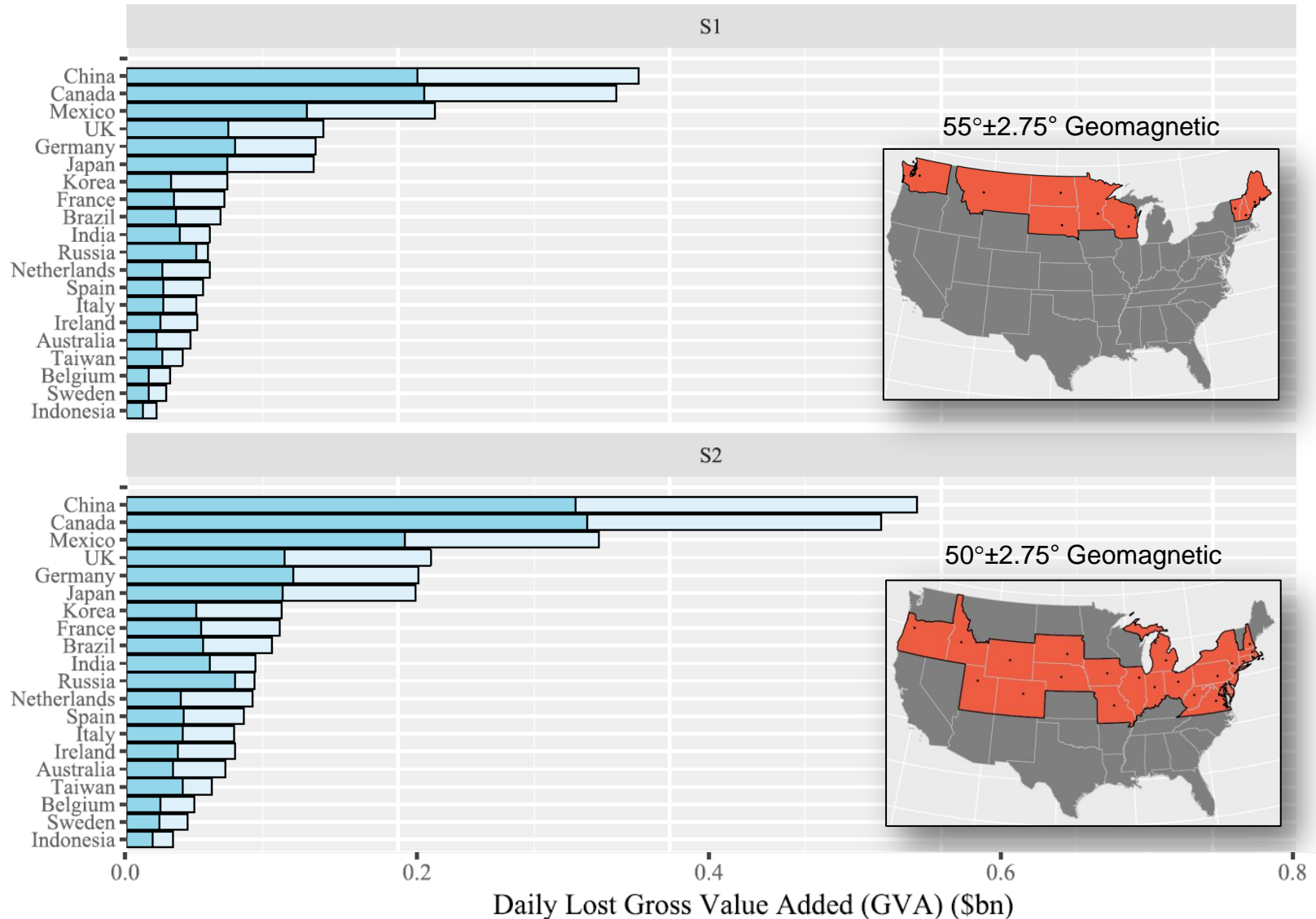
■ Global downstream loss (\$bn)

■ Global indirect upstream loss (\$bn)

# S1/S2 Impact by Industrial Sector

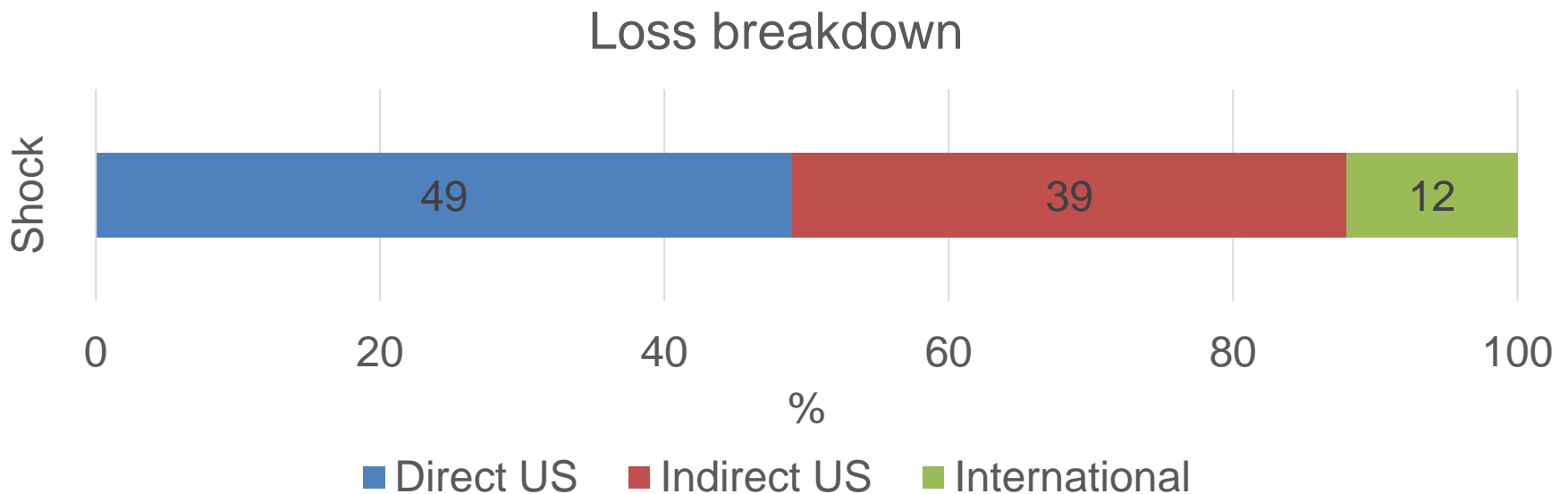


# S1/S2 Impact by International Supply Chain



# Conclusions of the Academic Paper

*The direct economic cost incurred within the blackout zone only represents approximately half of the total potential macroeconomic cost*



Cost-benefit analysis of investment in space weather forecasting and mitigation must take account of indirect domestic and international supply chain loss

# Conclusions

*Transparency leads to dialogue, debate and refinement of these estimates*

# Conclusions

The contribution of this paper includes:

1. A tool for industry and government to understand potential daily loss
2. Kick-starting more dialogue between physicists, geophysicists, electrical engineers **and** economists, insurers, actuaries etc.
3. Framing space weather impact in monetary terms makes this accessible to a whole new audience who want to know the potential risk

Work in progress: Multi-region global scenarios

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